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Efficient Level 2 Surveys Using Mechanical Detonators: Returning More Land, Creating More Wealth, Saving More Lives

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In a recent article,[4] Daniel Wolf and Steven Barmazel discussed a public health approach to demining. Here, they clarify and expand on some of the major points in that article.

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Introduction: Effective Mine Clearance Involves Triage

The biggest problem facing demining enterprises is this: productivity of individual deminers is so low that total labor costs per unit of land cleared remain exorbitant—despite minuscule wages in mine-affected countries. Clearing agricultural land in developing countries typically costs many times the land's expected mine-free annual revenues. Most remediation is uneconomic for public and private parties alike, and *funding is never enough.*

Some demining agencies have responded with a triage system—classifying mine clearance operations into three levels of intensity and corresponding expense and limiting expensive clearance to critical areas.

In Level 1 (general location) Surveys, civilian employees gather anecdotal evidence to identify danger zones. *They do not enter suspect areas.* Though relatively cheap, they may be costly to local residents. According to Col. Alastair McAslan, former United Nations Demining Technology Assessment Officer, 100 suspect acres typically include only five acres with mines, but all 100 are put off limits because no one is sure exactly where the mines are. Worse, foragers learn to disregard danger postings because the odds favor them—even though losing the gamble means losing big.

Level 3 (complete clearance[1]) is at the opposite end of the scale from Level 1 Survey: it reduces risk as much as humanly possible, but is correspondingly expensive.

Level 2 (area reduction) Surveys in theory fill the gap between general location and complete clearance. Demining personnel enter suspect areas to delineate actual mine field perimeters, then mark or fence off the smaller mined areas, declaring areas outside to be *not mine fields* and releasing them for use. By greatly reducing quarantined land, Level 2 surveys slash economic burdens and lessen the need of foraging residents and livestock to enter suspect areas.

Most demining authorities would gladly fence off lower-priority mine fields, if they only knew their locations. But can they find the locations at a price they can afford? Unfortunately, the answer is usually no. Funding shortfalls have forced demining agencies to leave thousands of people exposed to unmarked mine fields while they devote themselves to clearing just a few. Faster, cheaper and more reliable Level 2 Surveys would allow officials to escape this dilemma. Mechanical substitutes for slow and vulnerable deminers can make this possible.

Choosing Between Good-Enough Statistics and Perfect Knowledge

Unless reliable maps or warning signs still exist, a mine field surveyor has to choose between two options: 1) Clearing an entire suspect area, finding the mine field but wasting considerable resources on unmined land; or 2) Taking samples, which is cheaper but inevitably runs the risk of missing mines. Not surprisingly, the latter is the usual choice. This transforms the Survey manager, like it or not, into a statistician, and the survey into a statistical problem.

The statistician's greatest concerns are randomness and sample size. All samples produce only approximations of the truth of the universe being sampled; the laws of probability dictate that larger, more random samples are more reliable than smaller, more selective samples; and very small samples run the risk of being dead wrong.

Great surveyors are familiar with local military tactics that help them focus on likely mine field locations. Traditional sampling involves cutting paths[2] through suspect areas. The pace is very slow because their tools are slow and they are trying to locate every mine in their way. Because the paths are narrow and not numerous, they

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sample only a tiny portion of the surveyed area.

To increase their odds of finding the mine field, surveyors cut multiple sample paths, eventually finding a mine field or satisfying themselves that none exist. As paths multiply, however, costs approach those of Level 3 clearance—reducing or even eliminating the cost advantage of Level 2 Surveys.

Mechanical Detonators Can Increase Sample Sizes Inexpensively

Though mechanical detonators detect a lower proportion of mines than do skilled deminers, locating a mine field requires finding only *some* mines, not *all* mines. The critical question is: Are the lower detection rates nevertheless sufficiently reliable for Level 2 Surveys?

The key to reliability is to increase area coverage to compensate for decreased detection rates. By design, detonators withstand blasts from AP mines, so in the same amount of time that deminers can sample only small strips (at significant risk), detonators can sample nearly all open areas and substantial amounts of vegetated areas (in safety). In fact, under many conditions, mechanical detonators will find mine fields faster than manual probing or detection.

Some mine clearance officials agree. Col. McAslan, commenting on Terra Segura's Armadillo™ landmine detonator system, said, "I could just run this back and forth until it encountered mines. I could map the blasts and thereby the mine field. I could do with a half-dozen men in two days what it presently takes me three platoons [about 100 deminers] and three weeks to do."[3] That's 96 person-hours versus 14,400—only 1/150 as much time.

How Reliable is Reliable Enough?

What detection rate is sufficient for Level 2 Surveys, given the larger areas sampled? In general, an effectiveness rate (the proportion of mines detonated in one pass) of 40-60 percent should be adequate to inspire confidence. To illustrate, assume a detonator with 50 percent effectiveness, i.e., coin-flipping odds. On a single pass, it will cover a high proportion of the suspect area and cause every other mine (on average) to betray its position by exploding. Detonating half the mines on a field's perimeter is sufficient to delineate approximate mine field boundaries. Numerous overlapping samples, meaning multiple passes, will further increase the probability that the sample findings approximate the "ground truth" (which, of course, cannot be known).

Every additional pass will detonate more mines, although detonation rates will fall with each pass as the "easy" mines disappear. But even a one-pass rate of 40 percent would reveal more mines—approximately 40 percent of mines encountered—and greater pattern detail, than completely cleared test paths cut across four percent of the same land.

Empirical research will improve understanding of what is required to assure adequate confidence in mechanical detonation sample findings, taking into account variables such as expected mine type (and other ordnance), soil composition, moisture content, vegetation, terrain, climate, infrastructure and the economics of the project. Just as the U.S. Navy develops algorithms that help marine minesweepers decide how many passes is enough to protect the fleet, so algorithms will be developed to help land operators choose the right equipment to use, the right way to use it, and where not to trust it, given local conditions.

To reiterate, where local knowledge and tactical speculation are unreliable, the larger sample sizes from detonators will produce information that is more dependable. At the other extreme, where mines have been emplaced according to accepted military doctrines and knowledge of location is good, traditional trench (path) samples can find mine fields effectively.

Let us be clear, mechanical detonators will not always be the best technique to apply in all situations. Operators will have to account for conditions when deciding where and how to use detonators. Once it is determined that terrain, infrastructure or other local variables do not contraindicate sampling by mechanical detonation, however, the large samples permitted by imperfect detonators will be superior to the small samples obtained by "perfect" human detectors.

The Practicalities: Conducting Detonation Surveys

Most mines are planted where people tend to walk. When emplaced according to military doctrine (as opposed to random sowing to induce terror), the logic of their placement helps the surveyors. Because belts of mines tend to be laid at set distances, about three feet apart, with a line behind and offset, a detonator likely would hit a mine with one side of its detonator array and a few feet along might hit another mine with the other side. When used only for finding a belt perimeter, the machine would be advanced until a detonation occurs, then withdrawn and advanced in another direction, as many times as necessary to confidently demarcate the boundary.

Perimeter delineation will be all that is required in areas where human incursions are infrequent and the best use of demining resources dictates marking or fencing but not clearance. It is also the least expensive, because it is faster and causes the least wear on the equipment.

In more populous areas it may be desirable to reduce potential risk still further by detonating as many mines as possible. We call this *density reduction*, in contrast to the *area reduction* of a normal Level 2 Survey—a Level 2.5 Survey, if you will. One would never declare such mine fields "cleared," and they would still require marking or fencing, as well as local education about the remaining danger. But if most exposed mines have been detonated (which is not possible using traditional survey methods), and most remaining mines are relatively inaccessible or insensitive, children, foragers and livestock ignoring mine field markings will be much more likely to walk out alive.

Cheap Surveying Increases Wealth and Well-Being

Mechanical detonators, by cutting Level 2 Survey costs ($1,250—2,500 (U.S.) per hectare is quite plausible) for a given national budget, could allow geometric improvement in effectiveness as measured by the number of casualties avoided and hectares of land returned to use, even if many mine fields are left marked and uncleared. A simplified example will serve to illustrate. See table 1.

The Cambodian Mine Action Center in its heyday cleared 10 square kilometers a year, spending on average almost $7,000/hectare. Let's assume, using high numbers, that Level 2 Surveying with mechanical detonators costs $2,500/hectare, and that 10 percent of a Level 1 surveyed parcel actually contains mines. For the same $7,000 that CMAC spent clearing a single hectare, mechanical detonators could locate mine field perimeters in 2.8 hectares. They would find mines in 0.28 hectare, which would be marked or fenced. So, for the cost of clearing one hectare, the Level 2 Survey would free for productive use more than 2.5 hectares.

If we use lower survey costs and a smaller proportion of suspect land actually mined, the result is even more remarkable. At $1,250 per hectare and only five percent of suspect land actually mined, that $7,000 frees up 5.32 hectares (5.6 hectares surveyed less 0.28 hectare that remains quarantined). So, simply by using mechanical detonators to conduct Level 2 surveys, mine clearance projects could return to use three to five times more land for the same money.

Mine-afflicted countries need to lower unemployment and provide work to ex-combatants. Won't labor-saving technology put local people out of work and delay economic recovery? Though superficially compelling, this objection does not withstand close examination because high productivity in mined area reduction would more quickly induce more employment than it displaces. A comparison of three scenarios (shown in the table).

Scenario 1, the CMAC scenario, maximizes employment in Year 1, using demining jobs. During Years 2–5, normal economic forces produce normal employment. In this example, 3,000 workers clear 10 square kilometers of land each year. Employment impact in Year 1 is 3,000. In Year 2, the 10 square kilometers of land released for agriculture employs 2,000 farmers (100 hectares/km^2 x 10km^2 x 2 farmers/hectare). With an economic multiplier effect of 1.5, the 2,000 farmers induce another 1,000 jobs elsewhere, for 3,000 jobs in Years 3–5. The total five-year impact is 14,000 job-years, assuming nothing else is happening to change the employment picture.

Scenario 2 maximizes the number of hectares freed, even at the cost of minimum Year 1 employment. In this case, 500 workers with mechanical detonators free 30 unmined square kilometers. Employment in Year 1 is only 500, but in Year 2, the newly-released land employs 6,000 farmers. With the economic multiplier effect, the employment impact in Years 3–5 is 9,000 jobs. The total five-year impact is 33,500 job-years. This is, in fact, the program that maximizes employment for the five years.

Scenario 3 balances Year 1 postwar employment—1,500 in demining and 1,500 in paid apprenticeships to train farmers and artisans—after which they go to full-time jobs. In this case, we assign 300 workers to Level 2 surveying because a substantial part of the budget is going instead to employment generation and training. Deminers will release and clear more land than in Scenario 1 but less than in Scenario 2. If 300 workers with mechanical detonators free up 18 square kilometers, and the other 1,200 clear four square kilometers (straight proportions of prior figures), then employment in Year 1 will be 3,000 (including trainees), Year 2 employment will be 4,400, and Years 3–5 employment will be 6,600 per year. The total five-year impact will be 27,200 job-years. Not surprisingly, this result falls between the other two scenarios.

Obviously, a hundred variables could affect actual results. But as the example illustrates, conducting Level 2 surveys with mechanical detonators could create great employment benefits.

Responses to Objections to Surveying with Mechanical Detonators

Mechanical detonation has many adherents, but the arguments of opponents persevere. One objection is that all technologies must achieve 100 percent in a single pass because

Table 1: Number of job-years created under three different scenarios.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total Job Years
Scenario 1	3,000	2,000	3,000	3,000	3,000	14,000
Scenario 2	500	6,000	9,000	9,000	9,000	33,500
Scenario 3	3,000	4,400	6,600	6,600	6,600	27,200

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there are personnel in the mine field. Another is that even during surveys all mines must be eliminated; leaving any number is irresponsible. A third is that flails can damage mines, or rollers can push them deeper into wet soil, creating serious problems for the deminers who encounter them later, or even miss mines altogether if the ground is uneven. An objection occasionally heard is that spreading additional metal around mine fields makes subsequent detection more difficult and expensive. Finally, some deminers fear that local people who see mines cleared during a survey may conclude that the land has been made safe when it has not.

Valid concerns underlie these objections, but defining and conducting the surveys properly can alleviate them. Unmanned mine-resistant devices, for instance, keep personnel out of harm's way. If a survey's objective is to quarantine the land for an indefinite period of time, then the obvious risk of leaving mines behind must be counterpoised not against the low consequent safety risks to surveyors, but against the high risks to the local population if the survey is not done because cheap methods are prohibited.

Concern about breakage, displacement and misses can be met by using the right machine: avoid flails if breakage is unacceptable; use heavy rollers only when the ground is fairly firm and flat; use ground-conforming disks or flails if the ground is very uneven. There is not one mechanical technology but many, each with its own particular virtues and flaws.

Spreading shrapnel around is a concern only when shrapnel-loaded mines are prevalent and metal detectors are the primary detection tool. Many mine fields have mainly blast-effect (low metal content) AP mines, however. If blow-in-place neutralization is acceptable, mechanical detonation usually will also be acceptable.

Finally, the responsible way to address the fear of local misunderstanding of the level of clearance is not to abandon cheap Level 2 Surveys, but to make local populations strongly aware that *only some mines* have been neutralized and that the mine fields remain extremely dangerous, albeit less so than before. The savings realized by the fast surveys will more than compensate for the additional costs to the local mine-awareness program.

Complete elimination of *found* mines and UXO is a valid requirement for surveys in two cases only: 1) The survey is being combined with the creation of safe paths through the mine field, in which case *of course* all mines must be removed from the paths (but only the paths); and/or 2) the site is scheduled for complete clearance in the near future, so any found mines may as well be neutralized.

Conclusion

Threat reduction is maximized when resources are used optimally across the entire national demining enterprise. Complete clearance would always be preferred over surveying and density reduction if it were as cheap and fast. But clearance is so costly that *clearing a few mine fields completely* may actually endanger more people because scarce resources are diverted from lessening the risk in *all mine fields*. We argued this point at length in the last issue of this journal.

No technology by itself has demonstrated 100 percent effectiveness, yet deminers continue to use their favored technologies, with which they are familiar and which they know how to use safely, shortcomings notwithstanding. Mechanical detonators likewise will produce a body of expertise governing the safe and effective use.

Level 2 Surveys are expensive now, but judicious use of mechanical detonators will make them more reliable and cheaper. In particular, they can slash labor costs—drastically. We'd like to see demining become so cheap that even poor landowners in developing countries can afford to have the job done. We may never see that. But each step demining takes toward such economic viability means that we can free more land, create more wealth and save more lives. And that's worth some fireworks. ■

Notes

[1] Clearance of miscellaneous unexploded ordnance conceptually occurs at Level 4, but as a practical matter is commonly included in Level 3 mine clearance.

[2] We used the term "sample path" instead of "sample trench" to avoid giving non-deminers the impression that the surveyor is actually digging a trench through the ground.

[3] Conversation with Daniel Wolf at demining policy conference, Sanford School of Public Policy, Duke University, Raleigh, North Carolina, USA, May 1, 1998.

[4] See *"The Necessity of Adopting a Public Health Approach to Demining,"* *Journal of Mine Action*, Summer 2001.

Biography

Daniel H. Wolf is President and Steven Barmazel is Publications Director of both Terra Segura International and Ploughshare Technologies. This article is based on a paper Mr. Wolf presented to the UXO/ Countermine Forum, New Orleans, April 9–12, 2001.

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